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Date: 28 June 2004

Heather Edwards

Dear Sir:

Attached hereto please find a substitute specification that replaces the specification filed initially with the present application. The substitute disclosure technically coincides with what was published in the PCT application WO00014684 differing therefrom style-wise only. No new matter has been entered.

Respectfully submitted,

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IMAGE PROCESSING METHOD

FIELD OF THE INVENTION

The present invention relates to the automatics and computation techniques and, more particularly, to methods of the preliminary image processing for sharpening and contrast enhancement.

DESCRIPTION OF THE RELATED ART

One of the methods known in the prior art is described in the Russian Patent No.2015561, published on 16.04.91, Int. Class G06K 9/40. According to this invention, the image correction is made basing on the analysis of the original image at the processed pixel and the local average value over some neighborhood of this pixel.

The method of that patent smoothes the original image, thus producing the smoothed image containing the low frequency components presenting the image background. Then the smoothed image is subtracted from the original one producing the second image containing high frequency components without background, said second image is then emphasized and added to the smoothed image.

The disadvantage of this method is that it emphasizes not only the useful signal but also the noise containing in high frequency image components, thus degrading the quality of the enhanced image.

The method according to U.S. Patent No. 5,038,388, published on 06.08.91, Int. Class G06K 9/40 smoothes the original image and subtracts the smoothed image from the original one thus producing the second image containing high frequency image components only. The second image is then adaptively emphasized so that the larger is a difference between the processed pixels and their neighborhood, the higher are their scaling factors. The output image is produced by adding the adaptively emphasized second image to the original image, thus sharpening the image without the noise amplification.

The solution disclosed in this patent does not provide any noise suppression as this method can only emphasize the high frequency image components that may contain a noise.

Furthermore, the disadvantage of this method known in the art is that it fails to improve considerably the sharpness of weak edges as such enhancement requires to emphasize high frequency image components in the regions where a difference between the processed pixel and its neighborhood is comparable to a noise level. Therefore, the edge enhancement in such regions causes the noise emphasis.

According to the image processing method disclosed in U.S. Patent No. 5,381,490, published on 10.01.95, Int. Class G06K 9/40, the largest difference Δ between the processed pixel and its nearest neighbors is calculated. Depending on the magnitude of this difference, one of the three processing modes is selected:

- edge enhancement by means of emphasis of the high frequency image components if $\Delta > T_1$, T_1 presenting the first pre-defined threshold value;
- reproduction of the original image, if $T_2 < \Delta < T_1$, where T_2 stands for the second pre-defined threshold value;
- image smoothing to suppress noise, if $\Delta < T_2$.

The first disadvantage of this method is that it may emphasize the noise selectively if the difference Δ varies around any of the threshold values for some neighboring pixels thus transforming small differences between neighboring pixels into larger ones by involving different processing modes for these neighboring pixels.

Furthermore, this method fails to provide quality enhancement of images with different noise magnitudes without tuning as the threshold values T_1 and T_2 are not selected adaptively.

Another approach to the noise suppression in images is described in U.S. Patent 5,563,963, published on 08.10.96, Int. Class G06K 9/40. The method of this patent operates by selecting a plurality of groups of neighbors for each pixel of the original image, each group being a square containing N x N pixels, N varying for example from 2 to 21. The processed pixel may be located at any position inside this square group of pixels. The least square best

fit plane (the planar approximation) is then used to approximate pixel values in each of selected pixel groups, and the new value for the processed pixel and the goodness of fit are computed based on the approximation for each group.

The target pixel of an enhanced image is produced by the weighted summing of all the new pixel values, thereat the higher is the goodness of fit for a group, the higher is the weight of this group.

The disadvantage of this method is that it fails to enhance edges as this method provides the noise smoothing only. Furthermore, this method requires substantial computation power to build least square approximations by hundreds of groups for each of hundreds of thousands of pixels.

The method disclosed in U.S. Patent 5,739,922, published on 14.04.98, Int. Classes G06K 9/40, H04N 1/40, operates by splitting an original color image into three isotropic frequency channels: low frequency image components (LF), medium frequency components (MF), and high frequency components (HF). Adaptive emphasis of the HF components and adaptive suppression of the MF components is then carried out, thereat the higher is the correlation between at least two of three basic image colors, the higher are multipliers for HF and MF image components. The enhanced image is obtained by summing the LF image components with the adaptively suppressed MF components and the adaptively emphasized HF image components.

The image processing method and apparatus described in said patent may have limited application as they are suitable for color images only since it is the correlation between color components only that is used for carrying out the image processing.

Furthermore, the noise suppression according to this invention is significantly limited, as the HF image components, that also contain noise, may be emphasized only and the noise suppression in MF image components is limited because no directional splitting of the original image is used.

No edge detection and enhancement can be obtained by this method as the isotropic frequency channels are used.

All these disadvantages degrade the quality of enhanced images.

The most relevant image processing method is described in U.S. Patent No. 5,351,305, published on 27.09.94, Int. Class G06K 9/40. According to this patent, a plurality of directionally filtered images is obtained from an original image by applying directional filters in a frequency domain. An enhanced image is then formed by selecting each target pixel either from a directionally filtered image, if a contrast edge is detected nearby the processed pixel, or from the original image otherwise. Thereat, the contrast edge is detected nearby the processed pixel by generating a standard deviation image and by producing an eigenvector description of this image. The eigenvector length is compared to a pre-determined threshold value to detect the edge.

The target pixel is equal to the corresponding pixel of the original image, if the edge was not detected nearby. Otherwise, the target pixel is selected from an image filtered with the most nearly corresponding direction of filtering.

While detecting edges, the eigenvector length may vary around the threshold value for several adjacent pixels. Whereby, the neighboring pixels of the enhanced image are selected from different images (the original image and directionally filtered image) thus causing the selective noise emphasis. This emphasis degrades the enhanced image quality.

Furthermore, original images may differ in their noise levels thus requiring different threshold values. The method does not include adaptive selection of the threshold value and, therefore, may not provide high quality processing of images with different noise levels.

Provided that the edge is detected nearby, the selection of pixels of the enhanced image is made from one of the plurality of directionally filtered images thus causing the complete suppression of all image structures that differ by their direction from the detected edge, notwithstanding that those structures can be clearly seen in the original image.

SUMMARY OF THE INVENTION

The object of the claimed invention is to provide an improved method for enhancing the image sharpness and contrast combined with simultaneous noise suppression.

The method of the present invention for simultaneous sharpness enhancement and noise reduction is comprised of the steps of: providing an original image as a matrix of discreet picture elements (pixels); splitting the original image into a low frequency channel and n-1 high frequency channels; detecting edges; and assembling an output image from the n frequency channels taking the detected edges into account.

The objectives of the invention are achieved by splitting of the original image into a low frequency channel and n-1 high frequency channels and edge detection by computation in each of n-1 selected high frequency channels of the correlation between processed pixel and its neighboring pixels, followed by the comparison of this correlation value with that for the corresponding pixels in other high frequency channels and with the threshold value for this channel. Based on the results of comparison, the weighting coefficients are formed for each pixel of each of n-1 high frequency channels. The assembly of the output image is made by summing each pixel from the low frequency channel with all products of the corresponding (by their location in the image) pixels of n-1 high frequency channels by their weighting coefficients.

The objectives of the invention are also achieved by selection of m of n-1 high frequency channels ($2<m<=n-1$) in such a way that they differ one from another in the direction of principal passing only. Therewithal, the weighting coefficients for any of pixels of any of m high frequency channels is defined based on the comparison of its correlation value to the threshold value and to the correlation values of the corresponding (by their location in the image) pixels of other m-1 high frequency channels.

The objectives of the invention are also achieved by computation of correlation values as a product of the processed pixel value and the weighted sum of its neighbors, said weights

being anisotropic. The direction of this anisotropy corresponds to the direction of principal passing of the processed frequency channel.

Furthermore, the threshold value for any of n-1 high frequency channels is determined by analysis of distribution of values, or absolute values, of pixels in this channel. The threshold value may be also determined by analysis of distribution of values, or absolute values, of pixels of the original image.

The image processing method claimed as the invention is characterized by the following features that distinguish it from the most relevant method known in the prior art:

1. while splitting the original image into n frequency channels, a low frequency channel and n-1 high frequency channels are selected;
2. the value of correlation between the processed pixel and its neighboring pixels is used to detect edges in the image.
3. the output image is assembled by means of summing each pixel from the low frequency channel and all the corresponding (by their location) pixels from n-1 high frequency channels multiplied by their respective weighting coefficients.

Concerning the first feature, it should be noted that the extraction of the low frequency channel that is not a subject of any processing provides the distortion-free reproduction of large-scale structures of the original image in the enhanced image, as these structures are passed through the low frequency channel without any processing. Therewithal, the energy of noise passing through the low frequency channel without suppression is inherently low as most of the noise energy is concentrated at high frequencies.

Furthermore, the extraction of the low frequency channel helps reduce the computation power needed to find correlation values for n-1 high frequency channels as the subtraction of the local average value is required to compute correlation. This subtraction is made while extracting (subtracting from the original image) the low frequency channel.

Splitting the original image into several high frequency channels helps improve noise suppression (compared to selection of one or two channels) as the noise associated with pixels

of those frequency channels where edges were not found nearby is prevented from contributing to the enhanced image.

As far as the second feature is concerned, it should be noted that the edge detection by means of the correlation value between the processed pixel and its neighbors allows to find weak edges against a noisy background as the correlation value is close to zero for a typical noise, whereby the correlation values for adjacent pixels forming the edge are positive and of the similar magnitude. This difference in correlation behavior helps achieve high noise suppression combined with edge emphasis, thus significantly improving the image quality.

The edge detection based on the correlation between a processed pixel and its neighbors makes the method of the present invention applicable to various types of images, including color, gray scale and vector images, as well as multi-dimensional images. Furthermore, the use of this correlation provides a quantitative measure of the edge intensity for each image pixel. This feature allows performing the selective emphasis of edges characterized by certain intensity, for example, weak edges.

The third specific feature, namely assembling the enhanced image by weighted summing images from all frequency channels, helps remove completely the effect of the selective noise emphasis. This effect is caused by the selection of neighboring pixels from different frequency channels.

Furthermore, the determination of the threshold value by means of analysis of statistical distribution of pixels provides a high quality processing of images with materially different noise magnitudes without changing parameters.

Furthermore, use of anisotropic frequency channels and anisotropic weights makes the image processing method highly sensitive to weak edges.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the invention will appear from the following description in which a preferred embodiment has been set forth in detail, in

conjunction with the accompanying drawings of the apparatus that implements the claimed method, where

Figure 1 is a block diagram of the apparatus.

The preferred embodiment of the sub-units of said apparatus is shown in more detail in Figures 2 – 5, where

Figure 2 is a block diagram of a frequency channel splitting unit.

Figure 3 is a block diagram of one channel of a unit for computation of correlation values (a correlation unit).

Figure 4 is a block diagram of a unit to form the weighting coefficients (a weighting unit).

Figure 5 is a block diagram of a unit to assemble the output image (an assembling unit).

Figure 6 shows an example of pre-defined channel selection matrixes.

Figure 7 illustrates the operation of the frequency channel splitting unit.

Figure 8 is a graph showing an example of the dependence of the weighting coefficient on the correlation value.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figure 1, the apparatus contains an image source 1, an output of the image source being connected to an input of a splitting unit 2. A low frequency output 7 of the unit 2 is connected to an input 9 of an assembling unit 5, whereas all other outputs of the splitting unit 2 are connected to corresponding inputs of a correlation unit 3. These other outputs are also connected to inputs 10_1 - 10_4 of the assembling unit 5. Outputs of the correlation unit 3 are connected to corresponding inputs of a weighting unit 4, its outputs being inputs 8_1 - 8_4 of

the assembling unit 5. Thereat, an output of the assembling unit 5 is connected to an input of a memory unit 6, an output of this memory unit being an output of the apparatus.

Figure 2 shows the preferred embodiment of the splitting unit 2 in more detail. The unit includes a direct Fourier processor 11, an input of said processor being connected to the output of the image source 1. An output of the direct Fourier processor 11 is connected to first inputs of matrix multiplicators 12_0 - 12_4. Second inputs of the multiplicators are connected to corresponding memory units 13_0 - 13_4, these memory units holding pre-defined channel selection matrixes shown in Figure 6. Any of the matrix multiplicators 12_0 - 12_4 performs element-by-element multiplication of matrixes supplied to its two inputs. Outputs of the matrix multiplicators 12_0 - 12_4 are connected to inputs of the inverse Fourier processors 14_0 - 14_4. An output of the inverse Fourier processor 14_0 is connected to the input 9 of the assembling unit 5, and outputs of the inverse Fourier processors 14_1 - 14_4 are connected to the inputs 10_1 - 10_4 of the assembling unit 5, as well as to the corresponding inputs of the correlation unit 3.

Figure 3 shows in more detail one channel of the correlation unit 3. A memory unit 15 holds the image of the respective frequency channel. An input of this memory unit is one of the inputs to the correlation unit 3. The input is also connected to an input of a noise level-measuring unit 20, an output of the unit 20 being connected to a first input of a divider 19. A second input of this divider is connected to an output of a multiplicator 18, whose first input is connected to a first output of the memory unit 15. Other outputs of the unit 15 are connected to a weighting adder 17. An output of the adder 17 is a second input of the multiplicator 18. An address input of the memory unit 15 is connected to an address generator 16. An output of the divider 19 is the output of the channel of the correlation unit 3.

The noise level measuring unit 20 may be implemented according to the U.S. Patent No. 5,657,401, published on 12.08.97, Int. Class G06K 9/40, which is incorporated herein by reference.

All of the memory units are of a random access memory type, and DIMM PC133 128 Mb memory modules manufactured by IBM, or other similar ones well known in the art can be used for that purpose.

The weighting adder 17 may be implemented as eight scalar multiplicators and an adder (the number of the multiplicators is equal to the number of pixels in the neighborhood 22 of the processed pixel). Any of these scalar multiplicators has two functionally identical inputs and one output. The outputs of all scalar multiplicators are connected to inputs of the adder, and its output is the output of unit 17. First inputs of the scalar multiplicators are the inputs of the unit 17 and pre-defined weighting coefficients are supplied to second inputs of the scalar multiplicators.

Figure 4 shows the weighting unit 4. The four inputs of the weighting unit 4 are inputs of four rounding units 23_1 - 23_4, outputs of the rounding units are connected to inputs of an address assembling unit 24. An output of the unit 24 is connected to inputs of four look-up tables 25_1 - 25_4. The look-up table is a memory unit that stores the values of a weighting coefficient for any set of the four input correlation values. Outputs of the look-up tables 25_1 - 25_4 are connected to inputs of memory units 26_1 - 26_4, which accumulate values of weighting coefficients. Address inputs of the memory units 26_1 - 26_4 are connected to an address generator 27, whereas outputs of the memory units are connected to inputs of adders 28_1 - 28_4 for averaging weighting coefficients. Outputs of the adders are the outputs of the weighting unit 4.

Figure 5 shows the assembling unit 5. It consists of four multiplicators 29_1 - 29_4 and an adder 30. First inputs 8_1 – 8_4 of said multiplicators are connected to the outputs of the weighting unit 4, and second inputs 10_1 – 10_4 of said multiplicators are connected to the outputs of the splitting unit 2. Outputs of multiplicators 29_1 – 29_4 are connected to corresponding inputs of the adder 30 and an input 9 of the adder is connected to the output 7 of the splitting unit 2. An output of the adder 30 is the output of the assembling unit 5, and it is connected to the input of the memory unit 6 that accumulates an enhanced image.

The apparatus implements the claimed method as it is described hereinafter in more detail. Referring to Figure 1, an input image is generated by the image source 1. The Magnetic Resonance Imaging (MRI) unit may be used, for example, as the image source 1. This MRI unit produces an image of some cross-section of an object, this image being a matrix of discreet picture elements (pixels). The image is carried to the input of the splitting unit 2. The operation of the splitting unit 2 is described with a reference to Figures 2, 6 and 7. The input image is transformed to the frequency presentation by the direct Fourier processor 11. This frequency presentation contains complete information about the original image and is represented by the matrix of the same size as the input image. The matrix is passed to the identical matrix multiplicators 12_0 - 12_4. They perform element-by-element multiplication of the frequency presentation of the original image by pre-defined channel selection matrixes. The channel selection matrixes are stored in the memory units 13_0 - 13_4. Each channel selection matrix contains multipliers for all spatial frequencies of the frequency image presentation. Figure 6 shows examples of the channel selection matrixes.

More specifically, as the image is presented by a 2D matrix, its frequency presentation is also a 2D matrix. Figure 6a shows schematically a frequency presentation matrix. The horizontal and vertical spatial frequencies vary along axes k_x and k_y, respectively.

The zero spatial frequency corresponds to the constant image density. It is located at the crossing point (31) of axes k_x and k_y.

Points 32 and 33 represent the largest spatial frequency in a horizontal direction. The examples of images contributing to these frequencies are shown in drawings 34 and 35.

Similarly, the maximal spatial frequency in a vertical direction is located at points 36 and 37; the example of image contributing to these frequencies is illustrated by drawing 38.

The maximal spatial frequencies are located at points 39 - 42. The example of an image contributing to these maximal spatial frequencies is shown in drawing 43.

Medium spatial frequency in the horizontal direction is located at point 45. The example of image contributing to this frequency is shown in drawing 44.

The location of the spatial frequencies in drawings Figures 6(b-f) corresponds to the scheme depicted in Figure 6a.

Figure 6b shows schematically the predefined selection matrix for the low frequency channel, this matrix being stored in the memory unit 13_0.

The dark area 46 is filled by the unit values of the matrix elements. This area corresponds to spatial frequencies that pass through the low frequency channel. The white region is filled by the zero values of the matrix elements, therefore the frequencies of the white region do not pass through the low frequency channel.

Figures 6(c-f) show schematically the selection matrixes for four high frequency channels, the same notations as in Figure 6b being used thereat.

It should be noted that the sum of all channel selection matrixes Figures 6(b-f) is the matrix with all elements equal to 1. Therefore, all the information from the original image passes through at least one channel.

Referring now to Figure 2, each of the matrix multiplicators 12_0 - 12_4 forms on its output the matrix of the corresponding frequency channel in the frequency presentation. The inverse Fourier processors 14_0 - 14_4 transform these matrixes to the coordinate presentation.

The direct Fourier processor 11 and inverse Fourier processors 14_0 - 14_4 may be implemented based on the Fast Fourier Transform algorithm as described, for example, in: Cooley, J.M., Lewis, P.A.W. and Welch, P.D. *The Finite Fourier Transform* IEEE Trans. Audio Electroacoustics AU-17, 2, 77-86, 1969.

Figure 7 further illustrates operation of the splitting unit. Figure 7a shows the example of an input image, Figures 7(b-f) show the images formed on the outputs of the inverse Fourier processors 14_0 - 14_4, respectively, as a result of processing of the image shown in Fig.7a. The image of a low frequency channel 7b is carried from the output of the Fourier processor 14_0, being the output 7 of the splitting unit 2, to the input 9 of the assembly unit 5. The images of four high frequency channels are carried from the outputs of the Fourier processors 14_1 – 14_4,

being another outputs of the splitting unit 2, to the corresponding inputs of the correlation unit 3 and to the inputs $10_1 - 10_4$ of the assembly unit 5.

The further processing of these images will be described by the example of the first high frequency channel as this processing is identical in all high frequency channels.

Referring to Figure 3, the memory unit 15 stores the partial image of the processed channel. To compute the unnormalized correlation value, the processed pixel value 21 and values of pixels from its neighborhood 22 are sequentially selected from the memory 15. These values of pixels from neighborhood 22 pass to the input of weighting adder 17. The adder 17 implements the following operation on pixel values:

$$\mathbf{r} = \sum_{\mathbf{i}=1}^{\mathbf{N}} \mathbf{V_i X_i}$$

where N is a number of pixels in neighborhood 22 of the processed pixel (preferably N=8), V_i are the pre-defined weights (preferably $V_i=1/8$) and X_i are the values of pixels from neighborhood 22.

Alternatively, anisotropic weights V_i can be used for computation of the weighted sum r of the neighboring pixels. This approach is beneficial for cases where several high frequency channels differ one from another by the direction of their principal passing only. The direction of anisotropy of the weights V_i corresponds to the direction of principal passing for the processed frequency channel.

The multiplicator 18 forms a product of the weighted sum of neighboring pixels and the processed pixel value. This product is the unnormalized correlation value for the processed pixel. It is compared to the threshold value by dividing by this threshold value (output of the noise level measuring means 20) in divider 19. The result of this division is compared to 1.0 in the weighting unit 4. The processing described herein is repeated for all of the pixels of the partial image of the processed frequency channel.

The image of the first frequency channel passes also to the noise level measuring means 20. The noise level from the output of the means 20 is used as a threshold value to normalize correlation values by the divider 19. As a result, the matrix containing the correlation values for all of the pixels of the processed frequency channel is formed on the output of the correlation unit 3, these correlation values being normalized by the threshold value for the processed frequency channel.

The correlation values formed by the correlation unit 3 are carried to the weighting unit 4. Referencing now to Figure 4, those correlation values for four frequency channels pass to inputs of the rounding means $23_1 - 23_4$. These rounding means decrease the data precision to 4 or 5 bits.

The four rounded values from outputs of the means $23_1 - 23_4$, each containing 4 or 5 bits, are assembled into one 16- or 20-bit word by the address assembling unit 24. The address formed thereby is used as an input value for the four look-up tables 25_1 - 25_4. Each of them is a memory unit that stores values of the weighting coefficients for any combination of four correlation values in four frequency channels, such combination defining thereat the address formed by the unit 24 in a unique way.

Figure 8 shows the preferred dependence of the weighting coefficient W_i in the first frequency channel on the correlation value C_i in this channel and correlation values in other three channels, Δ representing the threshold value for this frequency channel. This dependence (on 2 variables C_i and L) is illustrated in Figure 8 by the plurality of curves:

curve A for $C_i \geq$ L,
curve B for $C_i = 0.7$ L,
curve C for $C_i = 0.3$ L,
curve D for $C_i = 0.1$ L and
curve E for $C_i = 0.01$ L.

The weighting coefficient W_i takes a minimal value for correlation values that are significantly smaller than the threshold value Δ. This part of dependencies Fig.8 provides the

noise suppression. The weighting coefficient smoothly increases from its minimal value to its maximal value for correlation values that are close to the threshold value Δ. Finally, the weighting coefficient takes its maximal value for correlation values that are significantly larger than Δ. This part of dependencies Fig.8 provides non distorted reproduction of edges.

Alternatively, the weighting coefficient W_i may increases from its minimal value to its maximal value while the correlation value is in the range between the threshold value Δ and the second threshold value being equal to the first threshold value Δ multiplied by some constant coefficient. The weighting coefficient W_i decreases when the correlation value becomes higher than the second threshold value. Therefore the weighting coefficient W_i takes a maximum for correlation values larger than the threshold value Δ. This behavior of the weighting coefficient W_i provides the emphasis of the weak edges thus improving the image quality.

The memory units 26_1 - 26_4 accumulate values of the weighting coefficients generated by the look up tables 25_1 - 25_4. The address generator 27 and adders 28_1 - 28_4 smooth those weighting coefficients in each frequency channel. The smoothing is obtained by summing (in the adder, for example, 28_1) the center value of the coefficient and its neighboring values being sequentially selected from the memory unit (for example, 26_1) by the address generator 27. The smoothed values of weighting coefficients formed on the outputs of adders (for example, 28_1) pass to the outputs of the weighting unit 4.

The operation of the assembling unit is described with a reference to Figure 5. The values of weighting coefficients for four frequency channels pass from the outputs of the unit 4 to the inputs 8_1 - 8_4 of multiplicators 29_1 - 29_4, whereas the pixel values of the corresponding frequency channels pass from the outputs of the splitting unit 2 to the other inputs 10_1 - 10_4 of these multiplicators. The products of the pixel values by the corresponding weighting coefficients generated by multiplicators 29_1 - 29_4 pass to the inputs of the adder 30. Thereto, the corresponding pixel value of the low frequency channel passes to the input 9 of the adder. The adder 30 adds the pixel value of the low frequency channel to all values of the

corresponding (by their location in the image) pixels of the high frequency channels, the latest values are multiplied (in multiplicators 29_1 - 29_4) by their respective weighting coefficients. The memory unit 6 accumulates pixels of the output image.

The embodiment described herein illustrates the method as applied to 2D scalar images. It is understood, however, that the claimed method may be applied similarly to 3D images. In this case, in the apparatus used to implement the claimed method, the number of frequency channel increases (preferably to 9 - 13), the 3D Fourier processors are used instead of 2D ones, and the number of pixels in the neighborhood of the processed pixel (used, for example, to compute a correlation value) is 26 instead of 8.

The claimed method may be applied also to processing vector images, particularly the color images. Thereat, the 3 components of a vector presenting a pixel value may correspond, for example, to the intensity of the 3 basic colors for this pixel. In this case, the scalar operations on pixel values, like Fourier transform and summing, are replaced by the corresponding vector operations as it is known in the art and the correlation is computed as a scalar product of the center pixel value and the weighted vector sum of its neighbors, thereat the vector adder contains as many scalar adders as the number of vector components.

While there was disclosed what is considered to be the preferred embodiment of the invention, it is to be understood that this embodiment is given by example only and not in a limiting sense. Those skilled in the art may make various modifications and additions to the preferred embodiment chosen to illustrate the invention without departing from the spirit and scope of the present contribution to the art. Accordingly, it is to be realized that the patent protection sought and to be afforded hereby shall be deemed to extend to the subject matter claimed and all equivalence thereof fairly within the scope of the invention.